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ARMCO SPECIAL STUDY REPORT

by

V. Ross Highsmith
Environmental Monitoring Division
Environmental Monitoring Systems Laboratory
Research Triangle Park, NC 27711

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OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

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A particulate monitoring network was established around the ARMCO (Integrated Steel Works, Middletown, Ohio) in March 1980. Total suspended particulate (TSP) and inhalable particulate samples were routinely collected within the network following prescribed procedures. The effect of off-mode particle collection by the TSP high-volume sampler was also investigated during the course of this study.

A summary and interpretation of the mass loading data are included in this report. These results were compared with pre-control ARMCO TSP data and with data currently being collected by the U.S. Environmental Protection Agency Inhaled Particulate Network.

The field operation requirements for this program were completed by PEDCo, Inc., under the sponsorship of the U.S. Environmental Protection Agency (Contract Number 68-02-3496). This report covers the results of particulate monitoring conducted from March 13, 1980, through August 2, 1981.

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FOREWORD

Measurement and monitoring research efforts are designed to anticipate potential environmental problems, to support regulatory actions by developing an in-depth understanding of the nature and processes that impact health and the ecology, to provide innovative means of monitoring compliance with regulations, and to evaluate the effectiveness of health and environmental protection efforts through the monitoring of long term trends. The Environmental Monitoring Systems Laboratory, Research Triangle Park, North Carolina, has responsibility for: assessment of environmental monitoring technology and systems; implementation of agency-wide quality assurance programs for air pollution measurement systems; and supplying technical support to other groups in the Agency including the Office of Air, Noise, and Radiation, the Office of Pesticides and Toxic Substances, and the Office of Solid Waste and Emergency Response.

The determination of human exposure to particulate matter is an area of importance to EPA. Innovative control strategies are being evaluated to determine their overall effectiveness in reducing particulate emission. This report presents and interprets particulate monitoring data collected in the vicinity of an integrated steel-making complex before and after the institution of approved control strategies for the reduction of fugitive dust.

Thomas R. Hauser, Ph.D.
Director
Environmental Monitoring Systems Laboratory
Research Triangle Park, North Carolina 27711

ABSTRACT

This monitoring study was initiated with the overall objective to develop a data base in support of an approved "bubble concept" strategy to reduce fugitive dust emissions in the vicinity of an integrated steel-making complex.

A particulate monitoring network was established around the ARMCO Integrated Steel Works, Middletown, Ohio, in March 1980. Total suspended particulate (TSP) and inhalable particulate samples were routinely collected within the network following prescribed procedures. The effect of off-mode particle collection by the TSP high-volume sampler was also investigated during the course of this study.

A summary and interpretation of the mass loading data are included in this report. These results were compared with pre-control ARMCO TSP data and with data currently being collected by the U.S. Environmental Protection Agency Inhaled Particulate Network. These results indicated that the "bubble concept" control strategies have contributed to an overall reduction in fugitive dust emissions in the vicinity of the ARMCO plant. In addition, these off-mode TSP sampler data indicated that passive particle collection biased the total TSP particulate sample by 10 to 12%.

The field operation requirements for this program were completed by PEDCo, Inc., under the sponsorship of the U.S. Environmental Protection Agency (Contract Number 68-02-3496). This report covers the results of particulate monitoring conducted from March 13, 1980, through August 2, 1981.

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SECTION 1

INTRODUCTION

The Environmental Monitoring and Techniques Branch (EMTB), Environmental Monitoring Division (EMD), Environmental Monitoring Systems Laboratory (EMSL), conducted a special study in the vicinity of the Middletown, Ohio ARMCO Integrated Steel Works Plant from March 13, 1980, through August 1, 1981. Particulate data generated from this network were collected for the Office of Air Quality Planning and Standards (OAQPS) in support of their assessment of the effectiveness of the "bubble concept" control strategy in reducing fugitive emissions. The "bubble concept" allows existing plants to treat all their emission points as though they were under a bubble. The plant reduces or eliminates pollution controls where costs are high, in exchange for compensating increased control at emission sources where control costs are low, in order to achieve a net reduction in overall plant emissions. These data were used by OAQPS to determine if application of the "bubble concept" lowered the total ARMCO plant emissions within the National Ambient Air Quality Standards[1] (NAAQS) for total suspended particulates (TSP).

Based on the 1974-1979 monitoring data collected in the proximity of the Middletown ARMCO plant, Butler County, Ohio, was designated as a TSP nonattainment area.[2] ARMCO responded by initiating an approved series of control measures aimed at lowering the plant's overall fugitive emissions.[3,4] The first fugitive emission control measures (paving slag haul road, Hot Strip Mill parking lot, and Cold Strip Mill parking lot) were initiated in 1978. From August 1978 through November 1979, the remaining parking lots were paved, an employee busing program was implemented, and designated perimeter parking areas were established. During the course of this study, the last two "bubble concept" control measures were completed: (1) paving of the East-West Freeway (July 1980), and (2) implementing road cleaning and coal pile spraying programs (August 1980). ARMCO's plan to establish a greenway around the plant is ongoing since September, 1981. Table 1 outlines the specific control measures and corresponding control strategy effective dates. Figure 1 displays the implementation of control strategies over time and relates the operation of the Environmental Protection Agency (EPA) network to the total "bubble concept".

Three independent networks (ARMCO, EPA, and Southwest Ohio Air Pollution Control) were established in the proximity of the ARMCO plant during 1980 to define pre- and post-controls fugitive dust concentration profiles. Some of the sampling stations operated in these three networks were identical to those sites operated during the earlier 1970s. One site in particular, Standard Radio Electronic Parts Company (SREPCO) was located within one quarter mile of the old ARMCO East Works site, the sampling location that generated the majority of noncompliance data during the earlier studies.

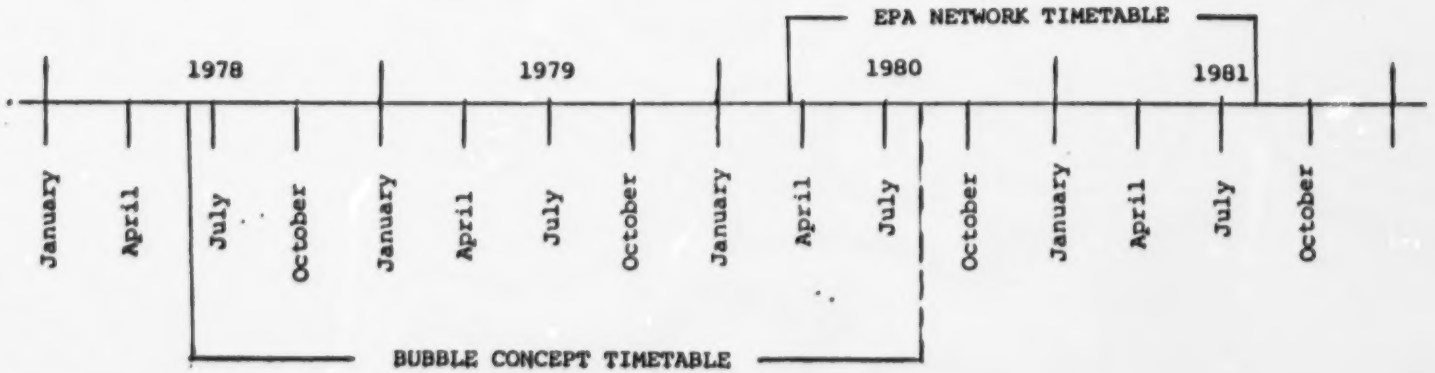
In addition to routine TSP high volume (hi-vol) sampling, two types of 15-μm particulate samplers (hi-vol samplers modified with a 15-μm size-selective inlet and 15-μm dichotomous samplers) were operated throughout the duration of the EPA network. These 15-μm data were used to relate past and present ARMCO data to the proposed 15-μm particulate standard. Two additional special studies were conducted. In the first special study, passive hi-vol samplers were operated at five sites. These passive sampler data provided an estimate of how much off-mode particulate collection biases the routine TSP hi-vol sample data. The second special study was an attempt to relate the particulate mass collected inside the SSI inlet with the corresponding particulate mass collected on the SSI hi-vol filter and collocated TSP hi-vol filter. At scheduled intervals, the SSI inlets were disassembled and the mass of the particulate matter >15 μm in diameter was determined. These data, when quantitatively compared to the corresponding TSP/SSI hi-vol data, could possibly be used to establish an inlet maintenance schedule based on site loading data.

This report briefly discusses the sampling operation and concentrates on the results of the EPA network. The operation and results of the other networks are reported elsewhere.[5] Information on site setup and routine sampling operations of the EPA network are described in detail in the PEDCo, Inc., report.[6]

TABLE 1. Chronology of Fugitive Dust Control Measures

DATE	CONTROL MEASURES
June 1978	Slag haul road paved
June 1978	Parking lots paved at Hot Strip Mill Parking lots paved at Cold Strip Mill
August 1978	Main Gate parking lot paved
November 1978	Contractors parking lot paved
December 1978	Wicoff (truck) parking lot paved
December 1978	Coke Plant gate lot paved
May 1979	Yankee Road lot paved
September 1979	Lefferson Road lot paved
November 1979	Employee busing program, abandon gravel parking, establish perimeter parking
July 1980	East-West Freeway paved
August 1980	Road cleaning and coal pile sprays began
Ongoing	Establish greenway

FIGURE 1. ARMCO "Bubble Concept" Timegraph



SECTION 2

CONCLUSIONS

In summary, these statistical summaries indicate that:

1. Based on the OAQPS/EPA report,[4] the ARMCO "bubble concept" control strategies have resulted in a total reduction of plant fugitive emissions. Although three network sites (Coke Plant, SREPCO, and Yankee Gate) yielded averaged TSP mass loadings in excess of the prescribed 75 $\mu g/m^3$ geometric mean standard, these site-averaged loadings are lower than the pre-1975 ARMCO East Works data reported for TSP. Data collected from the two fenceline sites (Coke Plant and Yankee Gate) may not be appropriate for use in determining compliance with the NAAQS. SREPCO site summaries were calculated from less than one complete calendar year of data and therefore may not be directly compared with the NAAQS. Additionally, no single day TSP value exceeded the 260 $\mu g/m^3$ standard during the course of this study.

2. The monitoring data reported herein, by themselves, do not indicate that the two control strategies implemented during the time period of this network yielded a statistically significant change in total plant emissions. An evaluation of pre- versus post-control mass loadings indicates that pre-control loadings are indistinguishable from post-control loadings.

3. The repeatability of mass loading collection for TSP and SSI samplers within this network was excellent (0.45% difference for TSP, 2.6% difference for SSI), as demonstrated by the collocated TSP and SSI sampler data.

4. Off-mode passive sampler collection, based on the 15 x 15 inch hi-vol samplers with sample savers, resulted in a collection of about 10 to 12% of the total TSP collection for each site evaluated in this study. This size hi-vol sampler is almost exclusively used by agencies in the National Air Monitoring Station and State and Local Air Monitoring Station (NAMS/SLAMS) network.

5. Correlations of the greater than 15 μm mass trapped in the SSI inlet with corresponding average SSI mass loading data were poor and therefore non-conclusive. However, the quantity of mass collected within the SSI inlet appears to be linked to the site characteristics and particulate loading/distribution, i.e., more industrial site samplers collected more material inside the SSI inlet. The inability to consistently sweep the greater than 15 μm diameter particles out of the inlet into a weighing container is most likely responsible for this poor correlation.

SECTION 3

EPA NETWORK SITES

Five particulate monitoring sites were selected by OAQPS and established around the ARMCO Plant in March 1980 (see Figure 2). A sixth site, SREPCO, was added in September 1980. One of the original sites, Oneida School, was forced to shut down in February 1981 because the building was to be demolished. Table 2 provides a brief narrative description of each EPA site and site instrumentation. A more detailed description is found in Section 2 of the PEDCo report.[6]

TSP hi-vol samplers were setup at five monitoring sites. Since fugitive dust emissions are related to TSP mass concentrations, pre- and post-control TSP loadings were compared in order to describe the overall effectiveness of the "bubble concept" strategies in reducing fugitive dust emissions. In addition to the TSP samplers, size-selective inlet hi-vol samplers (SSI) were set up at all six sites, and dichotomous samplers were set up at Yankee Gate and the ARMCO Research facility (hereafter, "Research") . Under normal operation, both SSI and dichotomous samplers used in this study were designed to collect particles in the 0- to 15-μm diameter range. The 15-μm sampler data obtained allowed an interpretation of both past and present ARMCO emission data with regards to the proposed new 15-μm particulate standard. Passive TSP samplers were installed at the original five sites to investigate the effect of off-mode particle collection (particles settling on the filter when the motor is not operating) on the total TSP sample. Past studies[7,8,9,10] have indicated a bias in TSP data resulting from off-mode collection. The EPA ARMCO network data were an excellent means to define this bias in TSP data, since passive collection is directly associated with the large particles inherent in fugitive emissions.

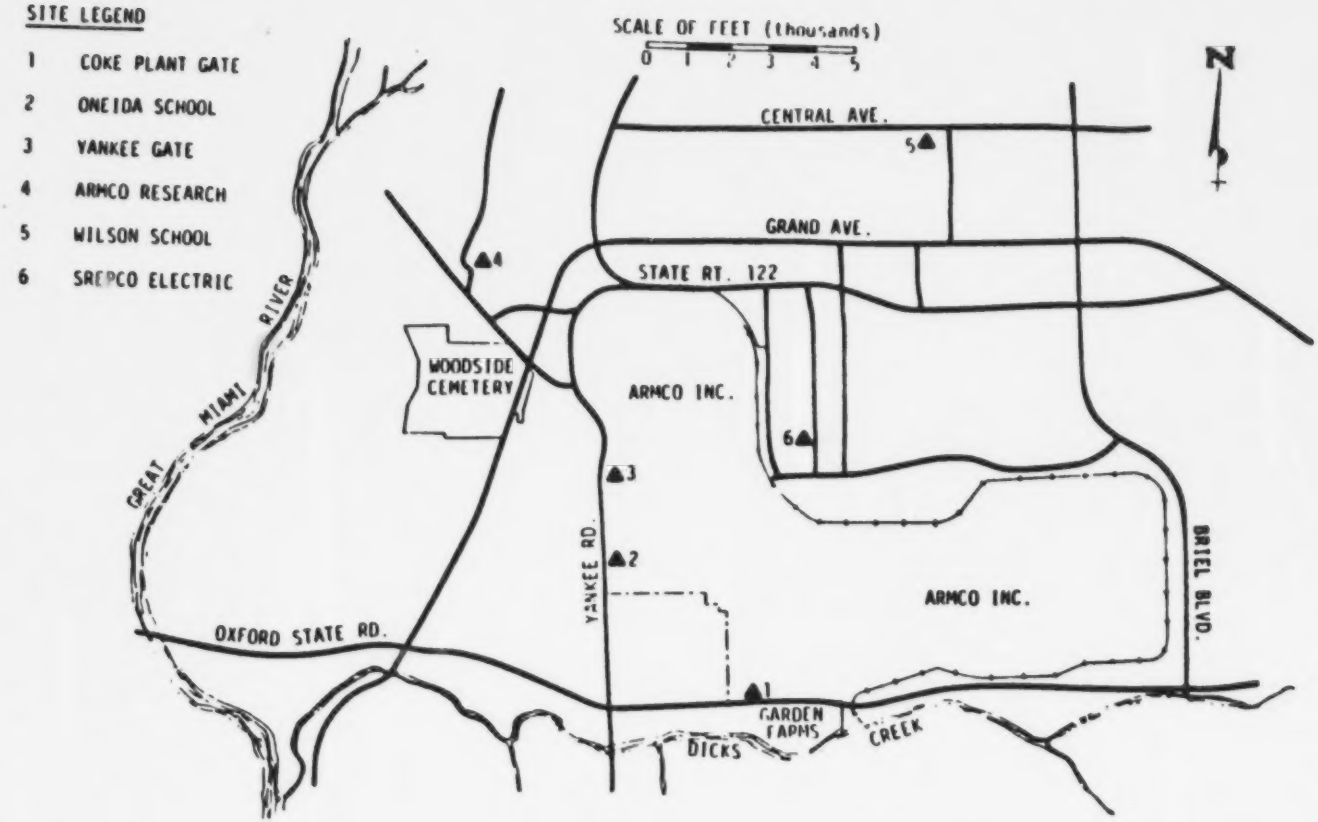


Figure 2 Middletown, Ohio showing sampling sites.

TABLE 2. SITE DESCRIPTION

Site	Description	Instrumentation
Coke Plant Gate	Industrial site located at the SW corner of the ARMCO facility by the Coke Plant. Site also influenced by nearby heavy traffic	TSP Collocated TSP SSI 15"x15" Passive Sampler 11½"x14" Passive Sampler
Oneida School	Light commercial site ca. 3/4 miles NW of the Coke Plant on school yard outside the facility boundary.	SSI 15"x15" Passive Sampler
Yankee Gate	Industrial site located ca. 1¼ mile NW of Coke Plant, ca. ½ mile N of Oneida School. Influenced by slag piles, heavy vehicle traffic, parking lot, and railroad.	TSP SSI Dichotomous 15"x15" Passive Sampler
ARMCO Research	Commercial site located ca.2½ miles NW of Coke Plant.	TSP SSI Collocated SSI Dichotomous 15"x15" Passive Sampler
Wilson School	Residential/light commercial site ca. 3 miles N of Coke Plant Gate.	TSP SSI 15"x15" Passive Sampler
SREPCO	Light commercial/residential site ca. ¼ mile from boundary of Plant ca. 1¼ miles N of Coke Plant Gate.	TSP SSI

SECTION 4

FIELD OPERATION

Hi-vol and dichotomous sampler field operation followed prescribed EPA procedures.[11,12,13] From March 13, 1980, through October 31, 1980, sampling was conducted every third day. During this period, every other sampling day corresponded to the Federal sampling schedule. Effective November 1, 1980, sampling was conducted every sixth day in accordance with the Federal sampling schedule. Sampler flow checks, calibrations, external audits, and routine administrative sampler operation documentation followed normal IP procedures.

In addition to the routine hi-vol and dichotomous sampler operation, two special studies (discussed in Section 9) were conducted during the course of this program.

SECTION 5

FILTER WEIGHING

All EPA network hi-vol and passive sampler filters were both pre- and post-weighed at the PEDCo laboratory following IPN procedures and quality assurance guidelines.[13,14] Statistics supporting the quality of these mass loadings were periodically prepared by the Quality Assurance Division, Environmental Monitoring Systems Laboratory, Research Triangle Park (QAD/EMSL/RTP), and are summarized in Table 4-3 of the PEDCo report. Dichotomous sampler filters were pre- and post-weighed by the EMSL/RTP laboratory following the IPN quality assurance protocol.[13] The procedures used to weigh the ARMCO dichotomous filters were identical to the processes used to weigh routine IP filters. Consequently, the quality of the IP dichotomous data sampler weighings is indistinguishable from the quality of the IP dichotomous data as reported.[15]

Throughout the project, the quality of the filter weighings was monitored by QAD/EMSL/RTP. Ten percent of all hi-vol and dichotomous filters were normally reweighed in accordance with standard Quality Control (QC) practices. As reported in the PEDCo report, only one batch of hi-vol sampler filters exceeded the acceptable QC weighing limits and required reweighing. The results of this reweighing and the corrective action taken by PEDCo are discussed in the PEDCo report.

SECTION 6

DATA VALIDATION PROCEDURES

Procedures routinely used to validate mass loading results are described in the PEDCo and EPA quality assurance plans. Once preliminary validation of the data had been completed, a second screening of the project data was conducted to compare sampler means, ratios, and high/low values. In addition, mass loading trends at individual sites and within the entire network were analyzed for uniformity of data. Statistical criteria[16] were used to screen outliers and flag questionable data. Outliers were retained for the data base but generally not included in subsequent trend analyses.

SECTION 7

QUALITY ASSURANCE

The results of routine sampler flow checks and the external audit team are provided in Tables 4-4 and 4-5 of the PEDCo report. Dichotomous samplers used in this network were not routinely field recalibrated. If a one-point sampler flow check (using an external audit orifice device) indicated that the sampler flow calibration was off by more than 10%, then the dichotomous sampler in question would have been replaced.

Using an external audit device, the mean percent difference calculated for 470 independent sampler flow checks was 1.9%. Mean hi-vol sampler flow shifts resulting from 47 field recalibrations were 1.17% of the original sampler flow. A comparison of collocated sampler mass loading data (TSP = mean 0.45% difference; SSI = mean 2.60% difference; see Table 10) yielded excellent agreement between the primary and collocated samplers. These data indicate uniform operation of the network samplers throughout the entire project. External sampler audits averaged -1.06% difference (sampler flow versus external audit device flow). The external audit results (less than ±10%) indicate that the samplers were correctly operated at the prescribed flow rate outlined in the manufacturer's specifications.

These network QA results indicate that the overall quality of the project data was acceptable.

SECTION 8

NETWORK RESULTS

Site statistical data summaries are provided in Tables 3 to 8. Both arithmetic ($\bar{x}$) and geometric (Xg) means were calculated for each sampler. Except where noted, discussions of site data are based on arithmetic data. Typical sampler ratios, (SSI/TSP, collocated sampler comparisons, dichotomous/hi-vol sampler ratios, coarse/fine dichotomous sampler ratios), are provided by site in Tables 9 to 12.

As expected, the Coke Plant Gate site yielded the highest averaged hi-vol concentrations (TSP: $\bar{x}$ = 100.3 $\mu g/m^3$, Xg = 92.9 $\mu g/m^3$; SSI: $\bar{x}$ = 69.9 $\mu g/m^3$, Xg = 65.1 $\mu g/m^3$). The highest TSP daily value (232.3 $\mu g/m^3$) was observed at the Coke site. Yankee Gate (TSP: $\bar{x}$ = 87.0 $\mu g/m^3$, Xg = 81.9 $\mu g/m^3$; SSI: $\bar{x}$ = 63.1 $\mu g/m^3$, Xg = 59.3 $\mu g/m^3$) and SREPCO (TSP: $\bar{x}$ = 88.7 $\mu g/m^3$, Xg = 79.8 $\mu g/m^3$; SSI: $\bar{x}$ = 64.6 $\mu g/m^3$, Xg = 58.9 $\mu g/m^3$) average hi-vol sampler loading values were slightly lower than the Coke Plant values. However, these data indicate that these two industrially influenced sites were nearly equally affected by the plant's daily emissions. SREPCO reported the network's highest SSI value (159.3 $\mu g/m^3$) and daily SREPCO SSI collections closely followed the Coke Plant site data. The two commercial/residential sites (Wilson School TSP: $\bar{x}$ = 59.2 $\mu g/m^3$, Xg = 55.0 $\mu g/m^3$; SSI: $\bar{x}$ = 49.9 $\mu g/m^3$, Xg = 46.5 $\mu g/m^3$ and Research TSP: $\bar{x}$ = 64.5 $\mu g/m^3$, Xg = 61.0 $\mu g/m^3$; SSI: $\bar{x}$ = 51.5 $\mu g/m^3$, Xg = 48.4 $\mu g/m^3$) yielded averaged values that were comparable to each other. However, Wilson School and Research averaged values were much lower than corresponding mass loading values observed at the industrially influenced sites. Oneida School SSI mass loading data ($\bar{x}$ = 61.2 $\mu g/m^3$, Xg = 56.9 $\mu g/m^3$) closely followed the Yankee Gate and SREPCO SSI data.

SSI/TSP ratios support the comparisons and conclusions noted above, with SSI/TSP ratios for the industrial sites being lower than those for the commercial/residential sites. Coke Plant (0.69), Yankee Gate (0.73), and SREPCO (0.74) SSI/TSP ratios indicate that about 30% of the total emissions at these sites are comprised of particles that exceed 15-µm in diameter. Only 10 to 20% of the particles collected at the other two sites appear to be larger than 15-µm in diameter, based on the Research and Wilson School SSI/TSP ratios (0.80 and 0.86 respectively). This again was expected, as fugitive dust emissions should heavily influence the TSP samples at the industrial sites.

Three sites (Coke Plant, Yankee Gate, and SREPCO) yielded geometric mean TSP data exceeding the prescribed 75 $\mu g/m^3$ geometric mean standard (92.9 $\mu g/m^3$, 81.9 $\mu g/m^3$, and 79.8 $\mu g/m^3$ respectively). These averaged values are lower than the ARMCO East Works TSP data reported earlier. Again, it should be noted that the data collected from the two fenceline sites may not be appropriate for determining compliance with the NAAQS. SREPCO site summaries were calculated from less than one complete calendar year of data and

TABLE 3. COKE PLANT GATE DATA SUMMARY
($\mu g/m^3$)

	TSP	TSP Collocated	SSI	SSI Collocated	Total Dichot	Coarse Dichot	Fine Dichot	Passive 15"x15" Sample Saver	Passive 11½"x14" Sample Saver
TOTAL PROJECT									
Arithmetric Mean	100.3	102.1	69.9					10.4	11.4
Std. Dev.	39.7	41.8	26.3					6.6	7.0
Geometric Mean	92.9	94.3	65.1					8.8	9.7
# Samples	106	109	117					71	69
MAX Value	232.3	231.2	140.3					34.3	36.9
2nd MAX Value	195.2	224.1	135.1					29.6	31.6
PRE-CONTROL									
Arithmetric Mean	104.5	108.9	76.4						
Std. Dev.	41.0	48.4	29.8						
Geometric Mean	96.4	98.5	70.2						
# Samples	40	42	43						
POST-CONTROL									
Arithmetric Mean	97.7	97.9	66.2					10.4	11.4
Std. Dev	39.0	36.8	23.4					6.6	7.0
Geometric Mean	90.8	91.7	62.3					8.8	9.7
# Samples	66	67	74					71	69

TABLE 4. ONEIDA SCHOOL DATA SUMMARY
($\mu g/m^3$)

	TSP	TSP Collocated	SSI	SSI Collocated	Total Dichot	Coarse Dichot	Fine Dichot	Passive 15"x15" Sample Saver	Passive 11½"x14" Sample Saver
TOTAL PROJECT									
Arithmetric Mean			61.2					7.7	
Std. Dev.			23.3					5.0	
Geometric Mean			56.9					6.4	
# Samples			78					40	
MAX Value			128.1					24.9	
2nd MAX Value			126.8					17.2	
PRE-CONTROL									
Arithmetric Mean			63.6						
Std. Dev.			22.0						
Geometric Mean			59.5						
# Samples			37						
POST-CONTROL									
Arithmetric Mean			58.9					7.7	
Std. Dev.			24.5					5.0	
Geometric Mean			54.7					6.4	
# Samples			41					40	

TABLE 5. YANKEE GATE ROAD DATA SUMMARY
($\mu g/m^3$)

	TSP	TSP Collocated	SSI	SSI Collocated	Total Dichot	Coarse Dichot	Fine Dichot	Passive 15"x15" Sample Saver	Passive 11½"x14" Sample Saver
TOTAL PROJECT									
Arithmetric Mean	87.0		63.1		58.7	31.3	27.4	9.2	
Std. Dev.	30.0		22.2		23.9	15.8	12.3	5.4	
Geometric Mean	81.9		59.3		52.1	27.5	24.6	7.8	
# Samples	104		109		96	96	96	63	
MAX Value	173.3		132.1		136.7			30.9	
2nd MAX Value	156.2		117.9		112.3			22.6	
PRE-CONTROL									
Arithmetric Mean	92.8		64.8		52.0	28.5	23.5		
Std. Dev.	30.0		21.1		20.5	14.4	10.1		
Geometric Mean	87.7		61.0		46.1	24.9	21.2		
# Samples	40		43		44	44	44		
POST-CONTROL									
Arithmetric Mean	83.4		62.1		64.4	33.6	30.8	9.2	
Std. Dev.	29.8		22.9		25.2	16.7	13.1	5.4	
Geometric Mean	78.6		58.1		57.9	30.0	27.9	7.8	
# Samples	64		66		52	52	52	63	

TABLE 6. ARMCO RESEARCH FACILITY DATA SUMMARY
($\mu g/m^3$)

	TSP	TSP Collocated	SSI	SSI Collocated	Total Dichot	Coarse Dichot	Fine Dichot	Passive 15"x15" Sample Saver	Passive 11¼"x14" Sample Saver
TOTAL PROJECT									
Arithmetric Mean	64.5		51.5	50.0	40.9	17.5	23.4	6.1	
Std. Dev.	21.0		18.2	16.9	15.2	7.8	9.6	3.2	
Geometric Mean	61.0		48.4	47.3	37.3	15.8	21.5	5.3	
# Samples	106		107	86	101	101	101	69	
MAX Value	122.8		109.6	112.4	79.7			17.1	
2nd MAX Value	122.4		102.1	92.9	78.6			16.8	
PRE-CONTROL									
Arithmetric Mean	69.7		54.2	55.1	44.5	18.9	25.6		
Std. Dev.	25.5		20.8	17.8	17.5	7.9	11.6		
Geometric Mean	64.6		49.9	52.0	40.1	17.0	23.1		
# Samples	39		40	13	37	37	37		
POST-CONTROL									
Arithmetric Mean	61.4		49.9	49.1	38.7	16.7	22.0	6.1	
Std. Dev.	17.4		16.4	16.7	13.3	7.7	8.0	3.2	
Geometric Mean	59.1		47.5	46.5	35.8	15.2	20.6	5.3	
# Samples	67		67	73	64	64	64	69	

TABLE 7. WILSON SCHOOL DATA SUMMARY
($\mu g/m^3$)

	TSP	TSP Collocated	SSI	SSI Collocated	Total Dichot	Coarse Dichot	Fine Dichot	Passive 15"x15" Sample Saver	Passive 11½"x14" Sample Saver
TOTAL PROJECT									
Arithmetric Mean	59.2		49.9					5.3	
Std. Dev.	22.9		19.2					3.0	
Geometric Mean	55.0		46.5					4.6	
# Samples	110		118					66	
MAX Value	122.7		103.3					18.8	
2nd MAX Value	117.5		103.2					12.6	
PRE-CONTROL									
Arithmetric Mean	62.1		48.6						
Std. Dev.	24.1		19.2						
Geometric Mean	57.4		44.9						
# Samples	38		43						
POST-CONTROL									
Arithmetric Mean	57.6		50.6					5.3	
Std. Dev.	22.3		19.3					3.0	
Geometric Mean	53.8		47.4					4.6	
# Samples	72		75					66	

TABLE 8. SREPCO DATA SUMMARY
($\mu g/m^3$)

	TSP	TSP Collocated	SSI	SSI Collocated	Total Dichot	Coarse Dichot	Fine Dichot	Passive 15"x15" Sample Saver	Passive 11½"x14" Sample Saver
TOTAL PROJECT									
Arithmetric Mean	88.7		64.6						
Std. Dev.	43.5		30.6						
Geometric Mean	79.8		58.9						
# Samples	61		61						
MAX Value	210.9		159.3						
2nd MAX Value	187.7		143.5						
PRE-CONTROL									
Arithmetric Mean									
Std. Dev.									
Geometric Mean									
# Samples									
POST-CONTROL									
Arithmetric Mean	88.7		64.6						
Std. Dev.	43.5		30.6						
Geometric Mean	79.8		58.9						
# Samples	61		61						

cannot be directly compared with the NAAQS. Contrary to the earlier studies, no single day TSP value exceeded 260 $\mu g/m^3$. The fact that the ARMCO network TSP averaged mass loading values are indeed lower than the data reported in the earlier study and that no TSP value exceeded the 260 $\mu g/m^3$ single day maximum, indicates that total plant emissions have been significantly reduced since the 1975 report. A comparison of collocated sampler data (Table 10: TSP = mean 0.45% difference; SSI = mean 2.60% difference) indicate uniform operation of the samplers.

Dichotomous sampler collections followed the patterns discussed above for site SSI/TSP samplers. Throughout the project, Yankee Gate total dichotomous loadings ($\bar{x}$ = 58.7 $\mu g/m^3$, Xg = 52.1 $\mu g/m^3$) significantly exceeded Research total dichotomous loadings ($\bar{x}$ = 40.9 $\mu g/m^3$, Xg = 37.3 $\mu g/m^3$). At the industrial site, again where larger particles were expected to heavily influence the total collection, the coarse particle fraction (2.5 µm - 15 µm in diameter) exceeded the fine particle fraction (0 - 2.5 µm in diameter) as shown by the 1.28 Yankee coarse/fine ratio. The reverse was expected and held true at the Research site as shown by the coarse/fine ratio of 0.80.

A comparison of the independent 15-µm samplers at these two sites (Table 11) yielded a dichotomous/SSI ratio of 0.78 at the Research site and 0.94 at the Yankee Gate site. The dichotomous/SSI ratio standard deviation for the Yankee Gate is nearly twice that for the Research site and supports a larger variance in particle size at the Yankee Gate site. This relative bias of sampler means, in comparable 15-µm samplers, follows data reported by other investigators and has been attributed to the passive collection of gases and particulate matter on the glass fiber filter.[17]

All site SSI/TSP ratios fall mid-range of the expected IP validation criteria (see Table 4-2, PEDCo Report), which indicates that these network data are representative of the IP program. Total dichotomous/TSP and dichotomous/SSI ratios (Table 11) are on the low side of the validation criteria. The Yankee Gate coarse/fine ratio (1.28, Table 12) is higher than the corresponding Research site (0.80). The difference observed is representative of the influence of fugitive dust emissions on the Yankee Gate site, since an increase in larger particles indicates an increase in fugitive emissions.

TABLE 9. SSI/TSP RATIOS

		Coke Plant	Oneida School	Yankee Gate	Research Facility	Wilson School	SREPCO
TOTAL PROJECT	Mean	0.69		0.73	0.80	0.86	0.74
	Std. Dev.	0.09		0.07	0.07	0.10	0.11
	# Samples	103		101	94	108	60
PRE-CONTROL	Mean	0.70		0.71	0.80	0.81	
	Std. Dev.	0.09		0.08	0.07	0.09	
	# Samples	38		38	36	38	
POST-CONTROL	Mean	0.68		0.75	0.79	0.89	0.74
	Std. Dev.	0.09		0.06	0.08	0.10	0.11
	# Samples	65		63	58	70	60

TABLE 10. COLLOCATED SAMPLERS

		Coke Plant TSP	Research Facility SSI
TOTAL PROJECT	Mean % Diff*	-.45	-2.36
	Std. Dev.	4.74	5.68
	# Samples	98	78
PRE-CONTROL	Mean % Diff	-.73	-5.57
	Std. Dev.	6.03	5.99
	# Samples	38	12
POST-CONTROL	Mean % Diff	-.27	-1.77
	Std. Dev.	3.76	5.47
	# Samples	60	66

*% Difference = $\frac{B - A}{A} \times 100$

TABLE 11. DICHOT/HI-VOL RATIO

			Yankee Gate	Research Facility
DICHOT TSP	TOTAL PROJECT	Mean	0.69	0 .63
		Std. Dev.	0.16	0.09
		# Samples	83	93
	PRE-CONTROL	Mean	0.58	0.64
		Std. Dev.	0.12	0.09
		# Samples	37	34
	POST-CONTROL	Mean	0.78	0.63
		Std. Dev.	0.12	0.09
		# Samples	46	59
DICHOT SSI	TOTAL PROJECT	Mean	0.94	0.78
		Std. Dev.	0.19	0.10
		# Samples	88	90
	PRE CONTROL	Mean	0.80	0.78
		Std. Dev.	0.15	0.09
		# Samples	40	34
	POST CONTROL	Mean	1.05	0.78
		Std. Dev.	0.15	0.10
		# Samples	48	56

TABLE 12. COARSE/FINE DICHOT RATIO

		Yankee Gate	Research Facility
TOTAL PROJECT	Mean	1.28	0.80
	Std. Dev.	0.65	0.32
	# Samples	96	101
PRE-CONTROL	Mean	1.37	0.80
	Std. Dev.	0.75	0.35
	# Samples	44	37
POST-CONTROL	Mean	1.20	0.80
	Std. Dev.	0.54	0.31
	# Samples	52	64

Figure 3 displays daily changes in TSP loadings at the most industrially influenced site (Coke Plant Gate) and the most residentially influenced site (Wilson School) through the entire sampling period. The concentration and scatter of site data are the result of the site characteristics, i.e., the industrial site tended to show higher concentrations and more day-to-day scatter than the commercial/residential site. The residential site data show lower concentration and less scatter, indicating that daily changes in the plant operation had little effect on this site's concentration. No definitive increases or decreases in individual site TSP concentration can be readily discerned from this plot, as would be expected for a significant change in plant operation that would reduce total emissions. Similar plots for the other TSP, SSI, or dichotomous samplers (not shown) follow the TSP plot shown in Figure 3, with proportionately lower mass loadings. Again, these comparisons indicate that little change in overall plant emissions occurred during the period of this investigation. This network operated during the implementation of the last control strategy only. The trends observed during this limited time period may not accurately reflect the overall effectiveness of the total "bubble concept" program, which was implemented from June 1978 to August 1981. OAQPS evaluated the entire time period and did find significant reductions in TSP concentrations, which they attributed to "bubble" control measures implemented prior to this study.[4]

Standard statistical techniques were employed to further evaluate the trends observed in Figure 3 and other sampler concentration plots. For each site sampler, the differences between pre- and post-control averaged sampler mass loading data, as shown in Tables 3 to 8 were subjected to the student t-test for non-paired data.[16] Left and right 95% confidence limits were calculated about the pre- and post-control data mean difference. A confidence interval containing zero indicates no statistical difference between pre- and post-control arithmetric mean values for the sampler being evaluated.

Table 13 summarizes the 95% confidence intervals calculated for each site sampler. Coke Plant SSI, Yankee Gate dichotomous, and Research TSP sampler statistics indicated that the pre- and post-control mean concentrations are marginally distinguishable. These statistical findings are most likely associated with the acceptable error expected for the sampling and filter weighing techniques. Other pre- and post-control sampler statistical data indicate that at the 95% confidence level, the control strategies implemented during the operation of the EPA network had no significant change in the concentration levels between the two time periods.

TABLE 13. STUDENT t-TEST FOR NON-PAIRED DATA

	Coke TSP-A	Coke TSP-B	Coke SSI	Oneida SSI	Yankee TSP	Yankee SSI	Yankee Dichot Total	Yankee Dichot Coarse	Yankee Dichot Fine
95% T	1.984	1.984	1.984	1.992	1.984	1.984	1.9867	1.9867	1.9867
Left Interval*	-9.007	-5.255	0.339	-5.847	-2.547	-5.936	-21.828	-11.485	-12.111
Right Interval*	22.607	27.255	20.06	15.247	21.347	11.336	-2.972	1.285	-2.489
Statistical Diff.	NO	NO	YES	NO	NO	NO	YES	NO	YES

	Research TSP	Research SSI-A	Research SSI-B	Research Dichot Total	Research Dichot Coarse	Research Dichot Fine	Wilson TSP	Wilson SSI
95% T	1.984	1.984	1.9901	-1.984	1.984	1.984	1.984	1.9799
Left Interval*	0.016	-2.899	-4.102	-0.332	-0.985	-0.280	-4.614	-9.296
Right Interval*	16.584	11.499	16.102	11.932	5.385	7.480	13.614	5.296
Statistical Diff.	YES	NO	NO	NO	NO	NO	NO	NO

*Left and right intervals calculated using standard t-test statistics for non-paired data. If "zero" is contained within the left and right intervals, then the pre- and post-control data are statistically indistinguishable, as would be indicated with a "NO" above.

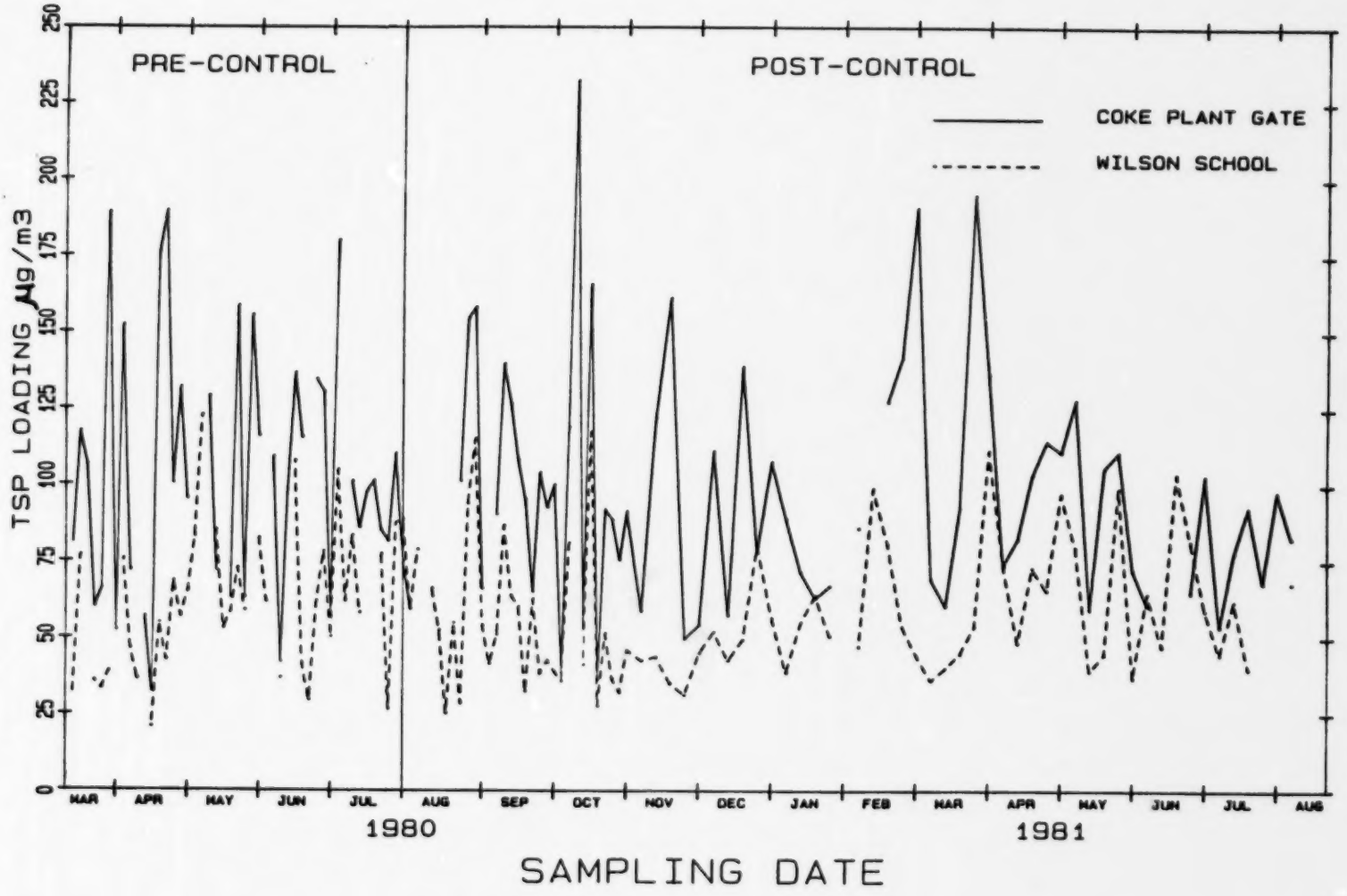


Figure 3. ARMCO special study daily TSP concentrations ($\mu g/m^3$).

SECTION 9

SPECIAL STUDIES

Two special studies were conducted during the course of this monitoring project (see Tables 3 to 8). Passive 15 x 15 inch hi-vol samplers were set up and operated at each of the initial five sites during August 1980. Only post-control passive sampler collection was conducted during this program. An additional 11½ x 14 inch passive sampler was operated at the Coke Plant Gate site. Externally, these passive samplers appeared to be identical to TSP hi-vols used in past and present networks. Internally, however, each 15 x 15 passive sampler had been modified as follows: (1) a General Metal Works (GMW) sample saver mechanism had been added, and (2) the hi-vol motor, flow controller, and Dickson recorder had been removed, leaving only the inlet with screen and faceplate for mounting filters. The 11½ x 14 shelter was not large enough to accept the GMW sample saver mechanism. Only the inlet, screen, and faceplate remained in the 11½ x 14 shelter. With the exception of the Coke Plant site, passive sampling was routinely conducted when the site TSP/SSI samplers were not in operation. When the site TSP/SSI samplers were in operation, the passive sampler mechanism was activated and a filter cover was raised to prevent the filter medium from collecting settling particulate matter. During periods when the site TSP/SSI samplers were not in operation, the cover was lowered, and the passive sampler filter exposed, allowing fugitive dust to collect. The two Coke Plant Site passive sampler filters (one 15 x 15 and one 11½ x 14) were exposed (open) during the entire sampling period, i.e., between filter changes. All passive sampler filters were changed at the same time the site TSP/SSI hi-vol and dichotomous samplers filters were changed. These passive samples were handled in the same manner as other field samples.

The difference between passive sampler filter gross and tare weights yielded the total mass (in grams) collected by the sampler during the off-mode operation. This total mass was then converted to an equivalent TSP sampler mass loading value, assuming optimum TSP operating conditions of 1.42 m^3/min and 24-hour collection as follows:

$$\frac{\text{collected mass (gm)} \times 10^6\ \mu g/gm}{1440\ \text{min} \times 1.42\ m^3/\text{min}} = \text{equivalent mass loading } (\mu g/m^3)$$

The averaged equivalent mass loadings for the network site passive samplers are summarized in Tables 3 to 8.

Both routine TSP hi-vol filters and passive sampler filters were changed at the same time and processed for mass determination in the same manner. Therefore, a ratio of passive sample equivalent mass loading ($\mu g/m^3$) to the corresponding site TSP mass loading ($\mu g/m^3$) provides a direct comparison of

the off-mode fugitive dust contribution to the TSP sample. Table 14 highlights these ratio comparisons.

Passive sampler equivalent mass loadings collections ranged from an averaged high of 11.4 $\mu g/m^3$ for the Coke Plant 11½ x 14 sampler to an averaged low of 5.3 $\mu g/m^3$ for the sampler at the Wilson School site. Again, the industrial sites showed more scatter in passive collection corresponding to larger changes in emissions, as demonstrated by the larger industrial site standard deviations calculated (Coke with $\sigma = 6.6$ $\mu g/m^3$ versus Wilson School with $\sigma = 3.0$ $\mu g/m^3$). These data indicate that the industrial site samplers are more heavily affected by fugitive dust emissions. Based on the passive sampler data, the post-control TSP sampler data reported in this study are biased positively by 10 to 12% of the reported value. This 10 to 12% bias can be directly attributable to off-mode collection during exposure time other than in the 24-hour sampling period. The comparison of the Coke Plant Gate 11 1/2 x 14 inch passive hi-vol sampler with the collocated 15 x 15 inch passive sampler yielded statistically indistinguishable results. These sample saver observations are in line with previous sample saver studies[7,8,9,10] that have investigated off-mode collection with and without passive loading prevention devices.

The second special study was an attempt to quantify the particulate matter greater than 15-μm in diameter collected within the SSI head during normal operation. At prescribed intervals, all SSI heads were field disassembled and the particulate matter brushed into a pre-weighed bottle. These bottles were returned to the laboratory for final weighing and mass determination.

This second special study had a two fold purpose. First, can the sum of the particulate mass collected on the SSI filter and the mass collected within the inlet be correlated to the corresponding site TSP hi-vol mass? A good correlation would support the effectiveness of the SSI to collect only particles below 15-μm in diameter. Secondly, does a correlation exist between the SSI inlet mass and SSI filter mass? If so, the amount of particulate matter collected in the inlet could be easily estimated from the sampler mass loading values, and proper sampler maintenance, including inlet cleaning, could be scheduled based on this estimation. These findings are important for both past and future data evaluations.

The findings of the second study were not conclusive, indicating the difficulty and inaccuracy of the field technique used. Table 15 summarizes the mass (in grams) of particulate matter collected from the site SSI inlets for each scheduled cleaning period. These data show that the more industrialized site inlets (Coke Plant, Yankee Gate, and SREPCO) collected a larger quantity of material than the non-industrialized sites. As usual, the residential-based Wilson School site collected the least particulate matter. Correlations between site particulate matter and corresponding averaged SSI and TSP mass loading data yielded statistically nonsignificant coefficient values. Future attempts to quantify SSI inlet collections must be carried out under more controlled collections.

TABLE 14. SAMPLE SAVER/TSP RATIO

		Coke Plant	Oneida School	Yankee Gate	Research Facility	Wilson School	SREPCO
*TOTAL PROJECT	Mean	0.12		0.11	0.10	0.10	
	Std. Dev.	0.06		0.07	0.05	0.05	
	# Samples	61		56	61	62	
	11½" x 14" VERSUS 15" x 15"						
*TOTAL PROJECT	Mean	1.16					
	Std. Dev.	0.29					
	# Samples	66					

*All sample saver data post control

TABLE 15. MASS COLLECTED IN SSI INLETS
(grams)

Date Site	4/1/81	6/6/80	10/13/80	2/27/81	3/26/81
COKE	0.5489[a]	1.0404	0.6655	-----[e]	2.8840
ONEIDA	0.0161[a]	0.0348	0.2758	1.0291[d]	-----[b]
YANKEE	0.1908[a]	0.0343	0.3277	-----[e]	1.0099
RESEARCH	0.0357[a]	0.0110	0.2210	-----[e]	0.3009
RESEARCH (collocated)	-----[b]	0.0143[a]	0.1677	-----[e]	0.3592
WILSON	0.0194[a]	0.0099	0.0684	-----[e]	0.0895
SREPCO	-----[b]	-----[b]	0.1312[c]	-----[e]	0.8123

a. Initial sampler cleaning.

b. Site sampler not on line.

c. Initial sampler cleaning - includes months of operation.

d. Sampler taken off line.

e. Sampler inlet not cleaned at this time.

SECTION 10

VALID SAMPLE COLLECTION

Table 16 highlights the individual site and network valid sample collection data. This table is slightly different from Table 32 of the PEDCo report, as discussed in Section 5 of this report. Additional sophisticated outlier/validation tests have been performed to eliminate statistical biases. The 87.2% average valid data capture for the network exceeds the projected 75% valid data goal and suggests that the ARMCO project produced a high degree of valid data.

TABLE 16. VALID DATA CAPTURE

Site	Sampler	Total Expected	Total Voided	% Voided
Wilson School	TSP	124	14	11.3
	SSI	124	6	4.8
SREPCO	TSP	63	2	3.2
	SSI	63	2	3.2
Research	TSP	124	18	14.5
	SSI-A	124	17	13.7
	SSI-B	96	10	10.4
	Dichotomous	124	23	18.5
Yankee Gate	TSP	124	20	16.1
	SSI	124	15	12.1
	Dichotomous	124	28	22.6
Oneida School	SSI	48	20	20.4
Coke Plant Gate	TSP-A	124	18	14.5
	TSP-B	124	15	12.1
	SSI	124	7	5.6
TOTAL		1684	215	12.8

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